COMPARISON OF THE CLASSIFICATION PERFORMANCES OF CRIMINAL TENDENCIES OF SCHIZOPHRENIC PATIENTS BY ARTIFICIAL NEURAL NETWORKS AND SUPPORT VECTOR MACHINE

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In this study, a new approach based on Artificial Neural Networks (ANN) and Support Vector Machine (SVM) classifiers has been proposed in the determination of criminal tendency with biochemical data of schizophrenia patients. Classification was performed using the biochemical data of the offender and control group schizophrenic patients. The data were obtained from 100 schizophrenic inpatients in Elazığ mental and Neurological Disorders Hospital. The biochemical data used for the examination and classification of the criminal tendencies of schizophrenic patients were Triglycerides, Total Cholesterol, High Density Lipoproteins (HDL), Low Density Lipoproteins (LDL), Very Low Density Lipoproteins (VLDL), Sex Hormone Binding Globulin (SHBG), Oestradiol, Free Testosterone, Total Testosterone, Ghrelin, Copper (Cu) and Zinc (Zn). Biochemical data were classified using ANN and SVM. All data were normalized to before classification. In addition, classifier results were evaluated using cross-validation method. As a result of the classification performed, 87% accuracy and 89% accuracy were achieved by ANN and SVM, respectively. In the determination of the criminal tendencies of schizophrenic patients using their biochemical data, SVM classifier performed a more effective classification compared to ANN classifier. According to classification results, it was seen that the biochemical data used could be useful features in the determination of the criminal tendencies of schizophrenic patients.

Keywords: Schizophrenia, Artificial neural network, Support vector machine, Classification, Criminal tendency

1. Introduction

Schizophrenia is a state of mental disorder in which the individual withdraws into his/her inner world and his/her ability to perceive and interpret becomes different compared to normal individuals [1]. Among psychiatric diseases, schizophrenia comes to the forefront as a disease associated with aggressive behavior and potential of committing crime. In some studies, it has been shown that the potential of committing crime of schizophrenic patients is six times higher than the average of the society. [2] We can list some of the various reasons that push schizophrenic patients into crime as follows: Biological reasons, psychosocial reasons, economic reasons, drug addiction and so on.

In studies carried out using the biochemical data obtained from schizophrenic patients, various studies were carried out, such as the determination of schizophrenia disease with the help of statistical tests and the examination of those who commit crime or do not commit crime among schizophrenic patients [1], [3]–[6]. In addition, in previous studies, various computer-assisted systems were used for the classification of schizophrenia. These are the studies of the classification of schizophrenic and healthy individuals with ANN using Flurodopa PET imaging [7], automatic classification of family-based schizophrenia with SVM [8], the diagnosis of schizophrenia by machine learning using EEG features [9], the classification of patients with SVM using dynamic sensitivity contrast (DSC) MRI [10], and the classification of schizophrenic patients with ANN using gene expression signatures in the blood [11].

ANN plays a significant role in the fields of image and signal processing. In image processing, processes such as pattern recognition and classification of images are performed with ANN. ANN can be divided into two categories as supervised and unsupervised learning. A multilayer feed-forward supervised ANN model was used in this study. SVM is a good classification technique based on statistical learning theory [12]. One of the important features of SVM is that it solves the problem by quadratic optimization method for classification and regression. The purpose of SVM is based on the method of obtaining the hyperplane which will most appropriately separate different types of data classes [13], [14].

In this study, it was aimed to classify the criminal tendencies of schizophrenic patients with ANN and SVM using their biochemical by means of a computer-aided method. In the study, the biochemical data obtained from schizophrenic patients were classified by being normalized in the range of [0-1]. The cross-validation method was used for the classification operation. The entire data set was divided into 4 parts. Each part was tested separately. The results were determined by taking the average of the values obtained from each part. Biochemical data used in the study are total cholesterol (tcol), very low density lipoproteins (vldl), high-density lipoproteins (hdl), low-density lipoproteins (ldl), triglycerides, sex hormone binding globulin (shbg), total testosteron (ttestos), estradiol, free testosterone (ftestos) ghrelin, Zn and Cu. The flow chart of the study is presented in Figure 1.

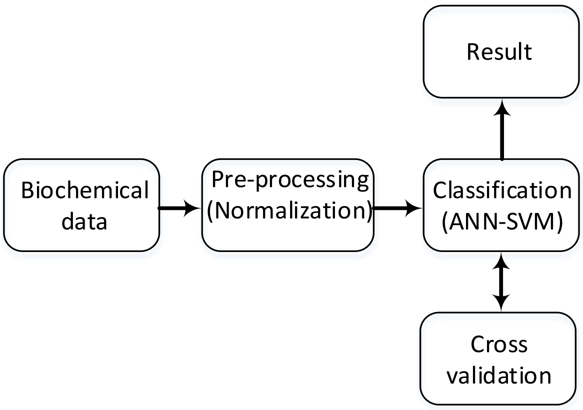

Figure 1. Flow chart of the study

2. Material and Method

2.1. Data Collection

Biochemical data were obtained from schizophrenic male inpatients in Elazığ mental and Neurological Disorders Hospital [1]. Blood samples were taken from the patient and control groups meeting the study criteria between 08:00 and 11:00 in the morning by taking into account the appropriate time and their fasting/postprandial states. Patients with severe physical illnesses, cholesterol-lowering therapy history, endocrinological disease and extreme obesity were not included in this study.

50 patients had at least one criminal record. The other 50 patients did not have any criminal record. The upper and lower limit value ranges of biochemical data are presented in Table 1. In addition, this study was carried out with the approval of Fırat University Directorate of Non-Invasive Research Ethics Committee.

Table 1. Biochemical properties and normal value ranges

Biochemical Features	tcol	trig	hdl	vldl	ldl	shbg	estra diol	ttestos	ftestos	Zn	Cu	ghrelin
Lower Limit	106	67	21	13	65	11,2	20,6	196	30,4	81	70	1,87
Upper Limit	252	203	53	41	183	81,8	49,7	874,5	178,11	170	164	21,15

2.2. Artificial Neural Network

Artificial neural networks are mathematical models designed by taking into account the biological structure of the human brain. ANN performs a learning using the information given to it. When an ANN is required to interpret a new information given after the learning process, ANN produces a result using the information it has learned [15]–[17].

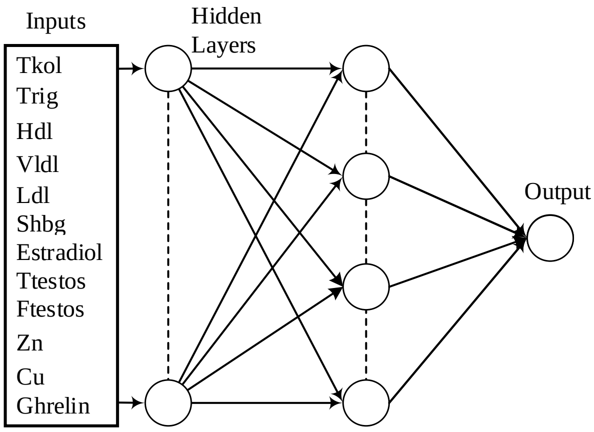

Figure 2. Multi-layer ANN model

ANN performs learning and classification operation using various training algorithms. The backpropagation algorithm, which is one of the frequently used algorithms in classification operations, was used (Figure 2). The details of the ANN model used are presented in Table 2.

Table 2. Structure of the ANN model

ANN structure	
ANN Model	Multilayer feed forward
Number of layers	3
Number of neurons	Input:12 Hidden:12 Output:1
Initial weights	Random
Activation functions	Logarithmic sigmoid
Learning rule	Backpropagation algorithm

2.3. Support Vector Machines

SVM is a successful machine learning algorithm which was developed by Cortes and Vapnik used in classification problems and runs according to the principle of structural risk minimization [18]. SVM aims to find the optimal hyperplane while performing the classification operation. In addition, the SVM tries to maximize the distance between the support vectors that will be used to separate different classes during this process. Let (xi,yi) is a training set consisting of binaries. i=1,2,3…n, xϵRd is the input vector in d-dimensional space, yϵ(-1, +1) are class labels [18], [19].

As it is seen in Figure 3, the optimal hyperplane that will separate the two classes from each other should be determined. w is the weight vector or normal to the hyperplane, b is the bias value. To be able to achieve the hyperplane, the following inequality should be provided for all input data [13], [18].

$$y_i(w.x_i + b) \geq 1, \forall \in x_i \quad (1)$$

To be able to obtain the optimal hyperplane,||w|| value should be minimized. For this situation, $min\{1/2(||w||^2)\}$ equation needs to be solved. Lagrange multipliers (α) are used for the solution of the equation.

$$L = \frac{1}{2}||w||^2 - \sum_{i=1}^{n} \alpha_i [y_i(w.x_i + b) - 1] \quad (2)$$

As a result of the solution made, the decision function that will separate the two classes from each other is obtained as the following.

$$f(x) = sgn\left(\sum_{i=1}^{n} y_i \alpha_i (x.x_i) + b\right) \quad (3)$$

In cases where a linear discrimination is not possible in two-dimensional space, SVM tries to linearly separate the data set by mapping it to another feature space. It uses some kernel functions for this. The kernel functions used in this study are presented below [13], [18], [20], [21].

$$Linear: K(x,y) = (x.y) \quad (4)$$

$$RBF(Radial\ basis\ function): K(x,y) = exp\left[\frac{-\|x-y\|^2}{2\sigma^2}\right] \quad (5)$$

$$Polynominal: K(x,y) = (x.y+1)^d \quad (6)$$

$$Sigmoid: K(x,y) = tanh(\gamma.x.y + r)^d \quad (7)$$

σ, d, r, γ are the parameters of the kernel functions.

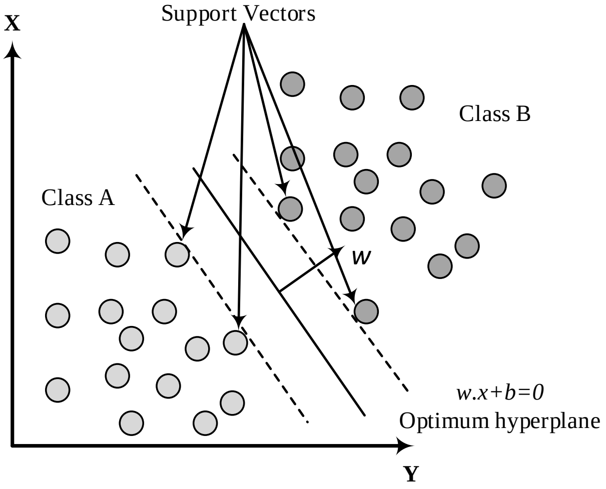

Figure 3. Determination of the hyperplane using SVM

2.4. Normalization and Cross-Validation

All data used in the study were normalized in the range of [0-1] according to the following normalization equation.

$$x_i = \frac{X_i - \min(x)}{\max(x) - \min(x)} \quad (8)$$

Cross-validation is a statistical method that evaluates the data set by dividing it into two parts as training and the test set. One of the cross-validation methods is the k-fold cross-validation method. In this method, the data set is divided into k pieces. While k-1 pieces are used as training data, the other piece is used as test data. This process is applied for all pieces. Thus, the entire dataset is used for both training and testing. In this way, the performance of the classification is determined by taking the average of the results found for each test data [22].

The indicators used to evaluate classifier performance are Sensitivity, Specificity and Accuracy. (TP (True Positive), TN (true Negative), FP (Flase Positive), FN (False Negative)) [23].

$$\text{Accuracy} = \frac{(\text{TP} + \text{TN})}{(\text{TN} + \text{FP} + \text{TP} + \text{FN})}$$

$$\text{Sensitivity} = \frac{\text{TP}}{(\text{TP} + \text{FN})}$$

$$\text{Specificity} = \frac{\text{TN}}{(\text{TN} + \text{FP})}$$

3. Results

Mean±Standard Deviation values of all biochemical data are presented in Table 3. Independent t-test was used to determine whether there was a significant difference between the data. The data smaller than $p<0.05$ were considered significant. $p<0.05$ was found for Trig, Hdl, Vldl, Shbg, Estradiol, Ftestos, Cu and Ghrelin.

Table 3. Range values of biochemical data [1] (Mean ± Standard Deviation)

Chemical Value	Tcol	Trig	Hdl	Vldl	Ldl	Shbg
Control Group	176,14±40,02	122,34±33,70	36,98±7,21	24,44±6,69	113,20±23,99	35,23±16,99
Offender	171,46±30,56	153,40±38,09	33,10±6,19	30,76±7,69	121,48±26,95	29,11±12,74
(*p*<0,05)	p>0.05	p<0.001	p<0.01	p<0.001	p>0.05	p<0.05
Chemical Value	**Estradiol**	**Ttestos**	**Ftestos**	**Zn**	**Cu**	**Ghrelin**
Control Group	33,21±9,62	455,10±105,13	63,94±25,23	110,60±17,90	109,70±22,32	4,45±2,45
Offender	27,57±10,21	465,85±164,93	109,29±30,30	102,86±21,38	130,21±19,44	11,51±5,45
(*p*<0,05)	p<0.01	p>0.05	p<0.001	p>0.05	p<0.001	p<0.001

For computer-aided classification, five features (Trig, Vldl, Ftestos, Cu, Ghrelin) that were found significant ($p<0.001$) according to t-test results were firstly classified. While 87% accuracy was achieved with ANN as a result of the classification performed using these five features, 81% (linear), 83% (rbf), 82% (polynomial) and 84% (sigmoid) accuracy was achieved as a result of the classification performed with SVM using some kernel functions (Tables 4 and 5).

Then, a classification operation was performed by using together three features (Hdl, Shbg, Estradiol) that were found significant ($p<0.05$) according to t-test results and the previous 5 features. While 83% accuracy was achieved with ANN as a result of the classification performed with eight features, 86% (linear), 85% (rbf), 79% (polynomial) and 85% (sigmoid) accuracy was achieved as a result of the classification performed with SVM (Tables 4 and 5).

Finally, a classification was performed using all 12 features. While 85% accuracy was achieved with ANN, 85% (linear), 84% (rbf), 83% (polynomial) and 89% (sigmoid) accuracy was achieved in the classification performed with SVM (Tables 4 and 5).

Table 4. ANN classification results

Number of Features	TP	FN	TN	FP	Acc	Sen	Spe
5	42	8	45	5	87%	84%	90%
8	43	7	41	9	83%	84%	82%
12	43	7	42	8	85%	86%	84%

Table 5. SVM classification results

Kernel function	Number of Features	TP	FN	TN	FP	Acc	Sen	Spe
Linear	5	40	10	41	9	81%	80%	82%
	8	44	6	42	8	86%	88%	82%
	12	46	4	39	11	85%	92%	78%
Rbf	5	43	7	40	10	83%	86%	80%
	8	44	6	41	9	85%	88%	82%
	12	44	6	40	10	84%	88%	80%
Polynomial	5	43	7	39	11	82%	86%	78%
	8	40	10	39	11	79%	80%	78%
	12	40	10	43	7	83%	80%	86%
Sigmoid	5	46	4	38	12	84%	92%	76%
	8	45	5	40	10	85%	90%	80%
	12	46	4	43	7	89%	92%	86%

The results of the classification performed using the biochemical data of schizophrenic patients are presented in tables 4 and 5. As a result of the classification performed using 5, 8 and 12 features, the best classification was obtained with the SVM classifier in which all 12 features were used. According to the results of computer aided classification performed, the best classification accuracy was obtained with SVM classifier using 89% sigmoid kernel function in the determination of criminal tendencies of schizophrenic patients.

4. Conclusions

It has been shown that SVM and YSA can be used effectively in determining the criminal tendency of schizophrenia patients using biochemical data. The best classification performance in the study was obtained when 12 biochemical features were used together. It was also seen that SVM generally gave better results than ANN in the classification performed using three different feature groups. In studies to be carried out in the future, criminal tendencies of schizophrenic patients can be evaluated using computer aided systems with different information about them (sociodemographic, etc.).

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